Aging Brain and Insulin Resistance

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Abstract

Brain aging is a natural process that is linked to reduced cognitive abilities, brain volume and neurochemical activity. There are many ways to slow this process down, one of them being diet. The question we seek to answer is "Can keeping a healthy BMI and lower insulin resistance/HOMA help prevent brain aging?". To answer this question, we conducted an analysis on data from an fMRI study of the aging brain on acute ketosis, using scatterplots and correlation tests to see the relationships between age vs HOMA, age vs BMI, BMI vs HOMA, and fasting insulin vs HOMA.

Introduction

As we continue to age and develop, our brain does too. According to the National Institute of Aging (NIA), brain aging is a natural process that happens over time that affects cognitive function. With brain aging comes slower recall, diminishing working memory and multitasking abilities, deterioration of the myelin sheath, shrinking brain regions, and less production of neurotransmitters like dopamine and serotonin. Although brain aging is inevitable throughout our lives, there are ways to slow the process down such as getting an adequate amount of sleep, effectively managing stress, and engaging in mentally stimulating activities. For our report, we plan to look into how diet can play a factor in slowing brain aging. The question we seek to answer in our analysis is "Can keeping a healthy weight and lower insulin resistance help prevent brain aging?".

Our analysis may benefit anyone who is concerned about their aging brain and want to keep their brains young and healthy for longer than average. It would be especially beneficial for older and elderly adults since they have a higher risk of developing neurodegenerative diseases like Alzheimer's and Parkinson's disease, which can accelerate brain aging. Looking at body weight index (BMI) and HOMA-IR (Homeostatic Model Assessment for Insulin Resistance) scores would help us understand how diet is related to brain aging in different age groups. Analyzing these variables could help people realize what they should change in their diet by adding or subtracting certain foods in their meals. This would be a step in keeping the brain and body healthy as both are interlinked.

To answer our question, we plan to use the data from an fMRI study of the aging brain in acute ketosis. We plan to create scatterplots from the data to analyze the relationships between BMI vs HOMA and age vs HOMA.

Data

To perform our analysis, we used data from an fMRI study of the aging brain in acute ketosis, which was found from openneuro.org, an open-source platform with public datasets containing neuroimaging data. The study involved scanning participants in a fasted state before and after they were administered insulin or glucose bolus based on body weight. Our data consists of 101 participants, aged 21-79, with the variables, participant_id, age, sex, BMI, bodyweight, fasting insulin (administered before or after), HbA1C, and HOMA.

Data Cleaning

To clean the data, variables irrelevant to our analysis like sex, bodyweight, and HbA1C were first removed before capitalizing the variable names to a more uniform syntax for easier reference. The data types for the remaining variables were converted for compatibility with Age, BMI, Fasting Insulin, and HOMA being numeric variables and Participant_ID being a categorical variable. We also removed observations that had missing values, leaving us with a filtered data set of 99 observations containing data for Participant_ID, Age, BMI, Fasting Insulin, and HOMA.

Visualizations

HOMA is a score combining glucose + insulin. when HOMA is high that means bad glucose fuel(insulin resistance) which can relate to brain aging.

Hypothesis1: "if age is older then HOMA will be increase"

Create scatter plot to visualize the age relate to HOMA.

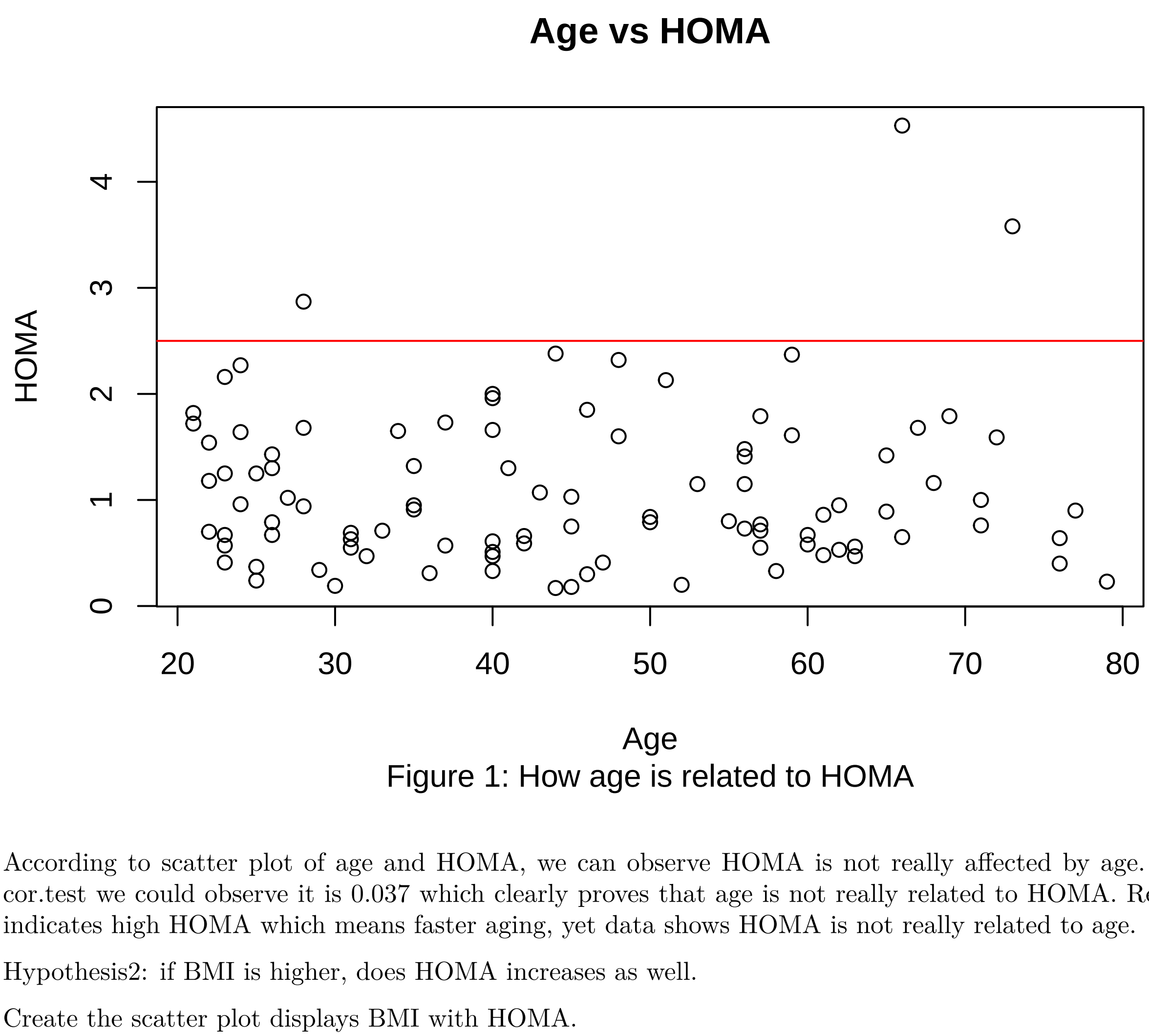

Figure 1: How age is related to HOMA

According to scatter plot of age and HOMA, we can observe HOMA is not really affected by age. With cor.test we could observe it is 0.037 which clearly proves that age is not really related to HOMA. Red line indicates high HOMA which means faster aging, yet data shows HOMA is not really related to age.

Hypothesis2: if BMI is higher, does HOMA increases as well.

Create the scatter plot displays BMI with HOMA.

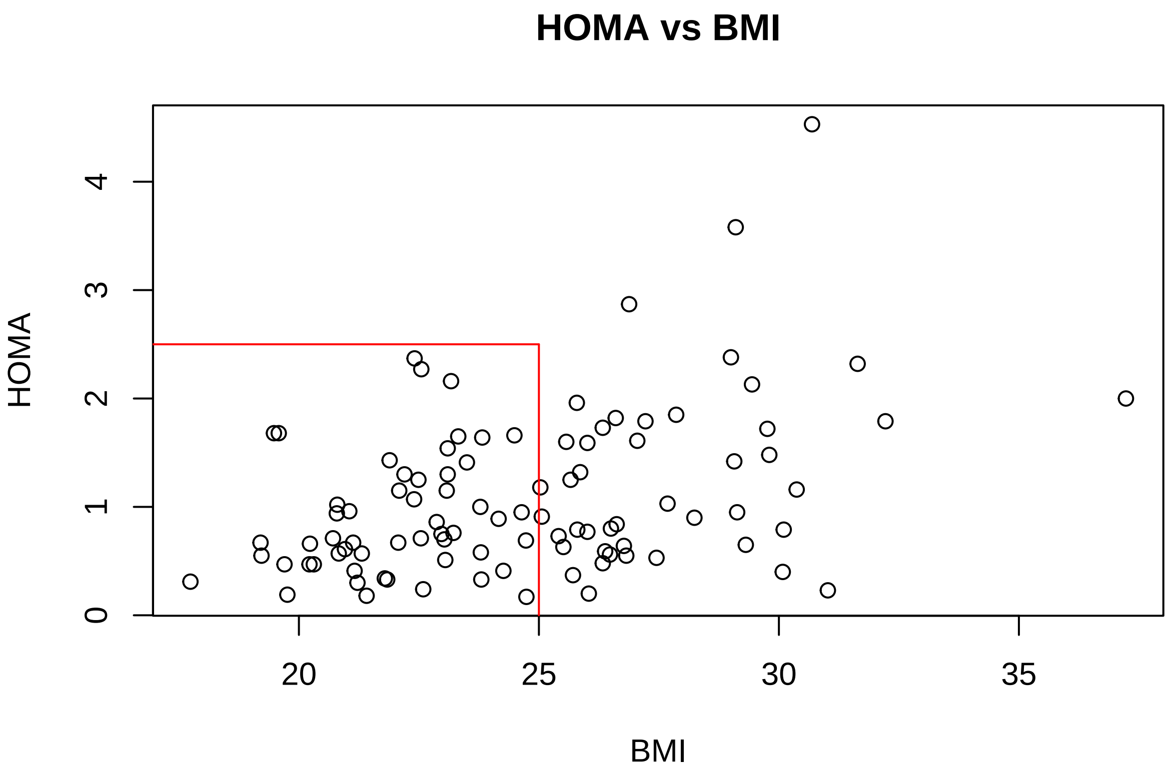

Figure 3: How BMI is related to HOMA

In the visualization, when BMI is in the normal range (< 25), there are no data points with HOMA values exceeding 2.5. As BMI increases beyond 25, which represents the overweight and obese range, several points appear above the HOMA threshold of 2.5. This visual pattern indicates a possible relationship between higher BMI values and increased HOMA levels.

high HOMA which can be high insulin resistance = glucose fuel less efficiently - brain's activity is depends on glucose, its main fuel source. - less efficient it is, there is high possibility that brain can aging faster.

Analysis

Age and HOMA plot (p-val = 0.7141, cor = 0.03728332)

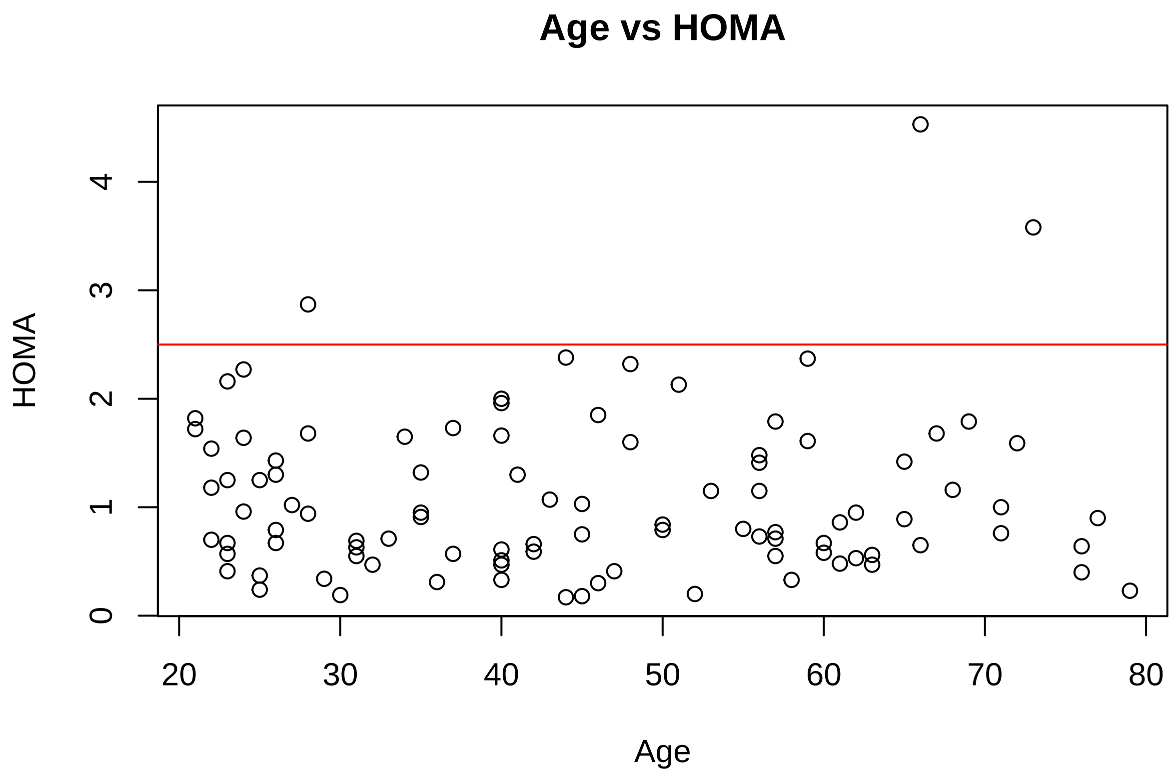

Figure 1: How age is related to HOMA

```
##
##  Pearson's product-moment correlation
##
## data:  age_vals and HOMA_vals
## t = 0.36745, df = 97, p-value = 0.7141
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.1613158  0.2329804
## sample estimates:
##        cor
## 0.03728332
```

Age and BMI plot

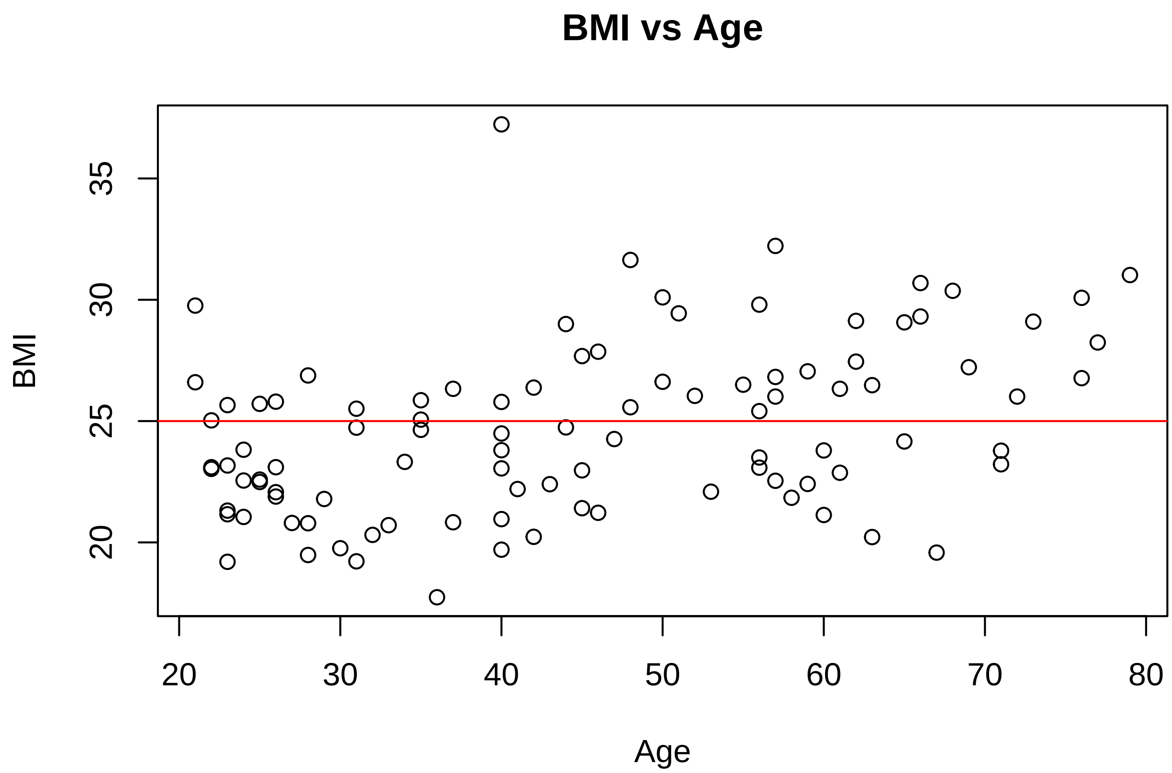

Figure 2: How age is related to BMI

```
##
##  Pearson's product-moment correlation
##
## data:  age_vals and BMI_vals
## t = 4.3216, df = 97, p-value = 3.75e-05
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.2220129 0.5551868
## sample estimates:
##      cor
## 0.401814
```

BMI and HOMA plot

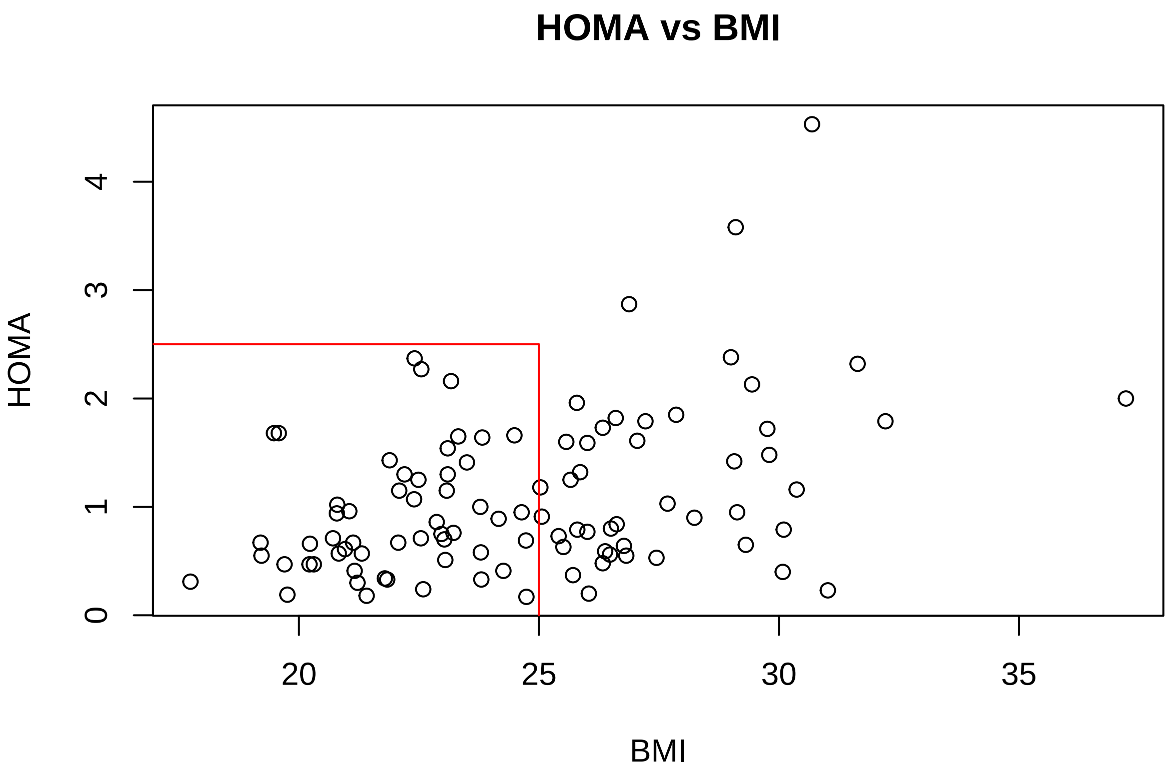

Figure 3: How BMI is related to HOMA

Fasting Insulin and HOMA

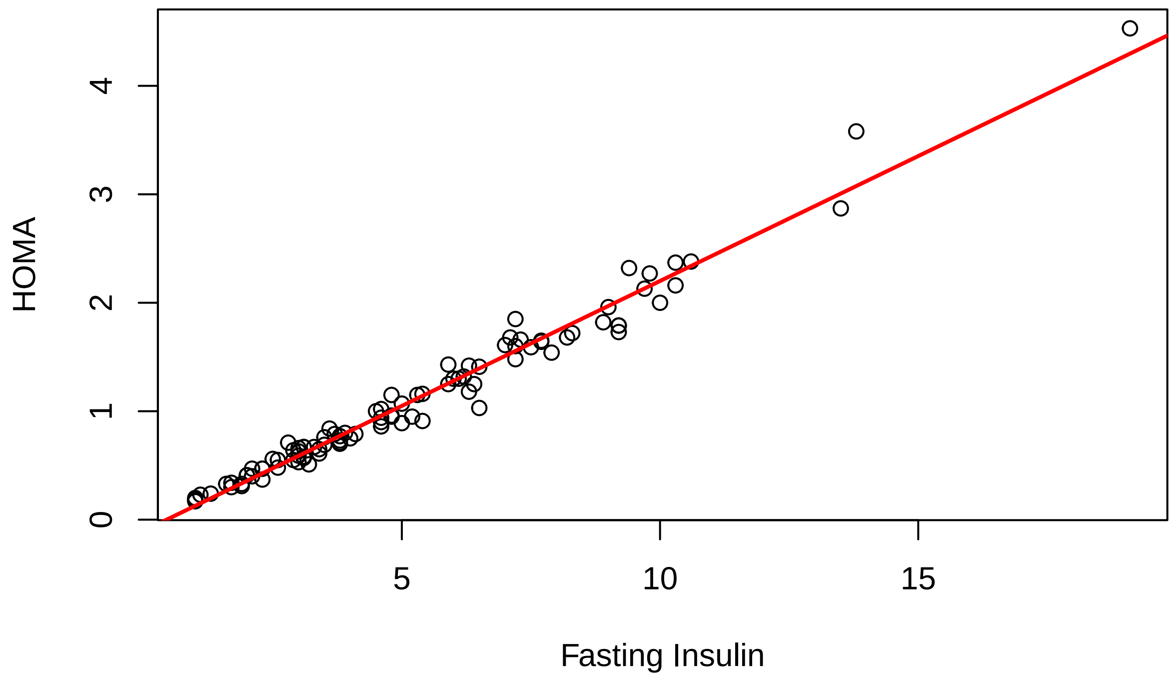

Figure 4: How fasting insulin is related to HOMA

```
##
##  Pearson's product-moment correlation
##
## data:  fast_insulin_vals and HOMA_vals
## t = 60.718, df = 97, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.9808125 0.9913340
## sample estimates:
##       cor
## 0.9870984
```

We performed correlation testing on our relevant variables such as age vs. HOMA, age VS BMI, HOMA vs BMI, and fasting insulin levels vs. BMI. The test between age and HOMA proved to be not significant as the cor = 0.037 indicating that there was no true correlation between the two.

Based on the Age vs BMI plot, BMI values appear to increase after age 50, with a higher proportion of participants classified as overweight or obese. While this does not prove causation, it suggests a possible association between age and BMI.

From the plot, we observe that when BMI is in the normal range (< 25), there are no HOMA values greater than 2.5. Once BMI exceeds 25, which falls into the overweight or obese range, some data points show HOMA values above 2.5. This observation suggests a possible association between higher BMI and increased insulin resistance.

For the fasting insulin and HOMA data, the scatter plot shows a strong positive linear pattern. The diagonal regression line closely follows the data points, indicating that as fasting insulin increases, HOMA values also increase in a nearly linear manner. Most observations lie close to the fitted line, suggesting a strong association between fasting insulin and HOMA, with relatively little dispersion at lower insulin levels. Additionally, the correlation coefficient is 0.987, which is very close to 1, indicating an extremely strong positive linear relationship between the two variables.

Conclusions

Overall, our results indicate that age alone does not show a meaningful relationship with HOMA, as the correlation between age and HOMA was near zero. However, age appears to be associated with BMI, particularly after age 50, where a larger proportion of participants fall into the overweight or obese category. In turn, BMI shows a clearer relationship with HOMA values. Specifically, when BMI is within the normal range (< 25), HOMA values remain below 2.5, whereas once BMI exceeds 25, several observations show elevated HOMA levels.

Since higher HOMA values reflect increased insulin resistance and poorer glucose regulation, these patterns suggest that BMI may play an indirect role in insulin resistance. Given that glucose is the primary energy source for the brain, impaired insulin sensitivity could affect how consistently the brain receives metabolic fuel. The visualization shows that individuals with lower or normal BMI tend to have healthier HOMA values, which may correspond to better insulin sensitivity and metabolic stability.

Furthermore, the very strong linear relationship observed between fasting insulin and HOMA (cor = 0.987) supports the idea that insulin regulation is a key factor underlying healthy HOMA levels. Maintaining lower fasting insulin levels is strongly associated with healthier HOMA values in our data, reinforcing the importance of metabolic regulation.

Taken together, while our analysis cannot establish causation or directly measure brain aging, the observed associations support the hypothesis that maintaining a healthy BMI and lower insulin resistance may contribute to metabolic conditions that are favorable for brain health. Based on our data and analyses, keeping fasting insulin levels low and HOMA values within a healthy range appears to be associated with reduced metabolic risk, which may help support healthy aging.

Member Contribution

Jonathan Wu - Formatting, Cleaning, ReadME Sung Woo - Data Visualization, Analysis Christie Wong - Report(Abstract, Intro, Data)